

1. γ -rays are produced by the β -rays of radium E in different materials, the greater in amount the greater the atomic weight of the material.
2. The γ -rays of radium E may be entirely secondary in nature. At all events, the γ -radiation can be greatly increased by a suitable disposition of the material and apparatus.

In conclusion, the writer wishes to express his best thanks to Prof. Rutherford for his kind interest in and advice during these experiments, and also to Prof. Boltwood for the preparation of the material employed.

On the Measurement of Specific Inductive Capacity.

By CHARLES NIVEN, F.R.S., Professor of Natural Philosophy, University of Aberdeen.

(Received February 9,—Read February 23, 1911.)

1. The discrepancy between Maxwell's theory of refraction and the values of the specific inductive capacities of some of the commoner liquids is well known, and the idea which naturally suggests itself is that the first values deduced for these capacities were obtained by using slowly alternating electric forces, and that if the period of alternation were greatly increased, a closer approximation to the values required by Maxwell's theory might be gained.

Among other methods employed is one by Thwing, founded on the principle of resonance, in which the period of the oscillations set up in a discharging circuit, which may be called the primary, is gradually altered till it agrees with the period of another fixed circuit, here called the secondary, in inductive connection with it. When the two periods are the same, it is assumed that the value of CL is the same for both, C being the capacity of one system and L the inductance of the circuit connected with it.

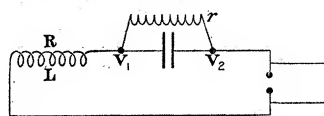
If we reverse Thwing's arrangement we may suppose the primary circuit fixed and modify the secondary till resonance is got. The measurements to be subsequently recorded were obtained in this way, using Fleming's cymometer as the adjustable resonator. In this way alternations were used whose frequency was comparable with a million per second, but the cymometer was only used to give comparative readings, the capacity of a

condenser with a liquid dielectric being compared with that of another with air between its plates. A diagram of the connections will be given later on when investigating the condition of resonance between the primary and secondary circuits.

Theoretically, the oscillations of a liquid condenser are complicated by the conduction which takes place through the liquid. The expression for its natural period is first found, and then the condition of resonance between it and the secondary circuit determined. This condition will be seen to be very simple in form, and reduces practically to that assumed by Thwing, viz., that CL is the same for both systems. Satisfactory determinations may be obtained in this way with liquids which are fair insulators, but if the liquid conduct to any extent, as is the case with water, alcohol, and other substances which have a high dielectric capacity, it is impossible to get it to stand up to the discharge or permit a spark to pass at all between the terminals of the circuit. To overcome this difficulty it was thought that if another condenser were put into the circuit, it might be possible to force the vibrations of the liquid condenser to take place, and this proved to be the case. The vibration period of this system is given by a somewhat complicated expression, but if the capacity of this additional condenser, introduced in series with the liquid one, be very large compared to the latter, it may be neglected, and the resulting period is that due to the liquid condenser. The additional condenser used was a battery of from three to five large Leyden jars. Its effect on the period of the discharge was tested by interposing it in the circuit of an air condenser having about the same capacity as the liquid condensers employed. It was found that the oscillation period was practically the same, whether the large condenser was introduced in series or left out altogether.

The results of some experiments made on water and alcohol are given at the end of this paper. They give values for the dielectric capacity agreeing with those found by other observers. Owing, however, to the heating effect which takes place with the large discharges used, it was found necessary to employ special means for securing that the liquid should be kept at a known constant temperature. Details of the arrangement used will be found in the paper.

2. The adjoining figure is the diagram for the discharge of a condenser



with resistance r between its plates. The wires from the terminals of the

spark-gap lead to the secondary terminals of an induction coil, which in the experiments made was interrupted by a mercury jet revolving in coal gas. L is the inductance of the discharging circuit, R its resistance. At the moment when the discharge passes the resistance of the spark-gap breaks down, allowing oscillations to be set up in the circuit. If V_1 and V_2 be the potentials at the terminals of the condenser, the current across the latter is $C \frac{d}{dt}(V_2 - V_1)$; that carried along the resistance r is $r^{-1}(V_2 - V_1)$;

thus the whole current in the circuit is $\left(r^{-1} + C \frac{d}{dt}\right)(V_2 - V_1) = i$.

But
$$V_1 - V_2 = \left(R + L \frac{d}{dt}\right)i,$$

and thus
$$\left(R + L \frac{d}{dt}\right)i + \left(r^{-1} + C \frac{d}{dt}\right)^{-1}i = 0.$$

If
$$i = e^{zt},$$

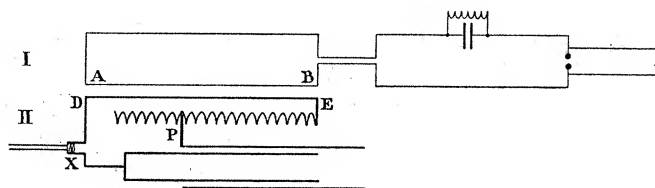
then
$$CLz^2 + \left(CR + \frac{L}{R}\right)z + \frac{R}{r} + 1 = 0,$$

the solution of which,

$$z = -\frac{1}{2}\left(\frac{R}{L} + \frac{1}{Cr}\right) \pm \sqrt{-\frac{1}{CL} + \frac{1}{4}\left(\frac{1}{Cr} - \frac{R}{L}\right)^2},$$

is mathematically of the same form as if the dielectric were perfectly insulating. The conduction through the liquid dielectric affects both the rate of damping and the period of oscillation, the former probably the most. It is unnecessary, however, to enter more minutely into a consideration of the relative magnitude of the different terms in the expression for z , because the next investigation shows that the condition for best resonance is of a much simpler form, and does not require such a discussion.

3. In the next diagram, Circuit I is that of the condenser, with inductance consisting of four turns of wire, in the form of a rectangle. Circuit II is that of the cymometer, consisting of a coil of copper wire of variable length,



and of a cylindrical condenser of variable capacity. The movable contact piece (P) varies the length of the coil introduced and the capacity of the

condenser simultaneously, so that the ratio of the two is approximately constant. The cymometer circuit also includes a small coil (X), inside which is a thermo-electric junction, the indications of which were read by a sensitive reflecting galvanometer.

The two circuits are connected inductively by the two straight conductors AB, DE, the coefficient of induction, M, between which is very small, so that, though currents are set up which are apparent in the sensitive cymometer, their reaction on the primary system is probably entirely negligible. The currents in the primary discharging circuit are therefore still given by the equation

$$\left[L \frac{d}{dt} + R + \left(r^{-1} + C \frac{d}{dt} \right)^{-1} \right] I = 0,$$

the solution of which is given by $I = e^{zt}$, and the equation for z is that given in the preceding article.

If we put $z = p \pm q\sqrt{-1}$, we see that if z_1 and z_2 be the two values of z ,

$$p^2 + q^2 = z_1 z_2 = \frac{1}{CL} \left(\frac{R}{r} + 1 \right).$$

The current J in the cymometer circuit is given by

$$\left(L_1 \frac{d^2}{dt^2} + R_1 \frac{d}{dt} + \frac{1}{C_1} \right) J + M \frac{d^2 I}{dt^2} = 0,$$

L_1, R_1, C_1 being the inductance, resistance, and capacity in this circuit; and substituting for I

$$J = -Mz^2 I / (L_1 z^2 + R_1 z + 1/C_1).$$

If we substitute for z its value $p + q\sqrt{-1}$, the denominator becomes

$$L_1 (p^2 - q^2) + R_1 p + C_1^{-1} + \sqrt{-1} \cdot q (2pL_1 + R_1),$$

which may be written $\Delta e^{a\sqrt{-1}}$, where

$$\Delta^2 = \{L_1 (p^2 - q^2) + R_1 p + C_1^{-1}\}^2 + q^2 (2pL_1 + R_1)^2.$$

The expression for J is

$$-Mz^2 e^{pt + (qt - a)\sqrt{-1}} / \Delta;$$

its amplitude, therefore, will be a maximum when Δ is least.

In dealing with this expression, we must remember that L_1 and C_1 are approximately proportional to each other, each being nearly proportional to the distance along which the contact maker is moved from the end of the spiral, or, what comes to the same thing, from the end of the inner tube of the condenser when the other tube is drawn fully off. As regards R_1 , it consists of two parts: a constant part, the resistance of the coil X, which is about 6 ohms, and a variable part, depending on the part of the spiral

introduced, and therefore also proportional to L_1 . If we call the length of the spiral employed x , we may put

$$L_1 = \lambda x, \quad C_1 = \kappa x, \quad R_1 = a + bx.$$

If, now, we seek the condition that Δ may be a minimum by the variation of x , we shall find that b always enters into the expression coupled with terms of the form $p\lambda$.

But we may estimate by measurement the resistance and inductance of the spiral per centimetre; they are approximately

$$1/90 \text{ ohm and } 4000 \text{ cm.}$$

and $p = 2\pi n$, where n may be taken about half a million. Thus $b = 10^7$ and $p\lambda = 10^{10}$ in round numbers; the variation of R_1 is therefore quite negligible. Treating it as constant, the condition for a minimum reduces to

$$\{\lambda x(p^2 + q^2) + \frac{1}{2}R_1 p\}^2 = \left(\frac{1}{\kappa x} + \frac{1}{2}R_1 p\right)^2,$$

and therefore

$$L_1 C_1 = (p^2 + q^2)^{-1} = LC/(R/r + 1).$$

In most cases R/r is quite negligible, so that we may take for the condition of resonance

$$C_1 L_1 = CL.$$

4. The theory of a liquid condenser in series with a perfectly insulating one may now be given.

The difference of potentials at the ends of the liquid condenser is

$$V_1 - V_2 = \left(C \frac{d}{dt} + r^{-1}\right)^{-1} I,$$

that at the ends of the insulating condenser

$$V_2 - V_3 = \left(C' \frac{d}{dt}\right)^{-1} I,$$

that at the ends of the coil having inductance and resistance

$$V_3 - V_1 = \left(L \frac{d}{dt} + R\right) I.$$

Thus for the current I we have

$$\left\{L \frac{d}{dt} + R + \left(C' \frac{d}{dt}\right)^{-1} + \left(C \frac{d}{dt} + r^{-1}\right)^{-1}\right\} I = 0.$$

Putting

$$I = e^{zt},$$

we obtain

$$Lz^2 + Rz + C'^{-1} + z(Cz + r^{-1})^{-1} = 0.$$

If C' be taken as infinite compared to C , this equation reduces to

$$Lz + R + (Cz + r^{-1})^{-1} = 0,$$

the vibration period is therefore the same as if the condenser C' were not interposed.

5. The method explained in the foregoing sections was applied to find the dielectric (or specific inductive) capacity of water and alcohol. The condenser used had the form of two concentric spheres whose diameters were respectively 9.5 (inside measurement) and 7.5 cm. Its capacity in electrostatic units was therefore 17.8, with air as dielectric. The outer sphere had two taps inserted at the top and bottom, and the lower tap was connected with a copper spiral, through which the liquid examined was allowed to flow, the whole system, spiral and condenser, being immersed in a large vessel containing water at a known temperature. When pure water, twice distilled, was run through the condenser, the cymometer reading gave a value for \sqrt{CL} of 14.5, the temperature in the outer containing vessel being 0° C., being kept constant by filling it with a mixture of snow and water. This was compared with the cymometer reading for an air-leyden formed of nine plates of glass coated on both sides with tin foil over an area 25 cm. by 25 cm., and separated by small pieces of glass each 0.38 cm. thick. The capacity of this condenser in electrostatic units is therefore

$$8 \times 25 \times 25 / 4\pi \times 0.38 = 1047 \text{ cm.}$$

The cymometer reading for this condenser was

$$\sqrt{CL} = 11.7.$$

The value for K_0 , the dielectric capacity of water at 0° C., is thus given by

$$\frac{K_0 \times 17.8}{1047} = \left(\frac{14.5}{11.7}\right)^2, \quad \text{or} \quad K_0 = 90.36.$$

By varying the temperature of the surrounding water the values of K_0 may be got at those temperatures. The following table is a record of some results thus obtained:—

Dielectric Capacity, K, of Water.

Temperature Centigrade.	Value of CL.	Value of K.	Variation for 1° C.
0	14.5	90.36	
7	13.65	80.06	
33	12.7	69.31	—0.64
59.5	11.65	58.32	—0.54
83	9.4	37.97	—0.63

Similar observations were made with alcohol as dielectric. Owing to its smaller dielectric capacity, the contact maker had to be moved further down

the scale, and the readings are perhaps not so accurate as in the case of water. A new form of condenser with a larger electrostatic capacity with air would have been preferable. The following were the results obtained with this substance :—

At 12° C.	K = 24·5
„ 64°·2 C.	K = 16·0

giving a variation between 12° and 64° of $-0\cdot161$ per 1° C.

I have pleasure in acknowledging the assistance which I received from Mr. A. E. M. Geddes, B.Sc., in conducting the above experiments.

Note on the Electrical Waves occurring in Nature.

By W. H. ECCLES, D.Sc., A.R.C.S., and H. MORRIS AIREY, M.Sc., F.R.A.S.

(Communicated by Sir A. W. Rücker, F.R.S. Received February 10,—
Read March 9, 1911.)

It has often been pointed out that whenever a lightning discharge occurs between a cloud and the earth, or between two charged clouds, it must give rise to a violent disturbance of the local electrical field, which will spread outwards as an electric wave from the region of the discharge. A lightning discharge may be aperiodic or oscillatory; accordingly a solitary wave or a train of waves, as the case may be, travels in all directions from the centre of discharge till its energy is dissipated by divergence into space or by the absorption of the atmosphere, and thus the disturbance may reach great distances.

In wireless telegraphy these vagrant waves are a source of great trouble to the telegraph operator. Being often very intense pulses or trains they frequently set the receiving antenna, whatever its natural period may be, into more violent vibration than do the signals being listened for, and not infrequently they compel the complete suspension of traffic. By those engaged in wireless telegraphy, all these and similar disturbances are called, variously, “atmospherics,” “strays,” “statics,” or “X’s.” When the usual telephonic method of receiving the Morse dots and dashes is employed, the strays are heard in the telephone as sharp clicks, as rattling noises, or as prolonged grinding or fizzing sounds. There is no doubt that some of these noises are due to other causes than vagrant waves. For example, it is well